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TABLE OF CONTENTS

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Session

Lignocellulosic Materials Science

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Mild Thermal Modification to Add Value to UK Grown Larch: Monitoring Quality, Physical Properties and Benefits

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Abstract

Many timber species in British forestry were selected for fast growth rate and imported from other regions within the temperate zone of the Northern Hemisphere. As these stands of trees have matured, the difference between UK grown and timber grown within the original provenance of the species has become apparent. One such example is Japanese larch (*Larix kaempferi*). The use of these home grown timbers presents challenges relating to growth rate and density. Japanese larch is a species of interest for diversifying softwood timber consumption in the UK, but sharply defined earlywood and latewood leads to several problems in machining and utilizing the timber. One option for enhancing timber quality is mild thermal modification. This paper presents a broad range of results from projects undertaken within Wales to develop and scale up the mild thermal modification process. The principal aims were to improve machinability and working properties of the timber in joinery applications.

By comparing timber from treatment runs with residence times in the treatment zone which ranged from 1½ hours to 5 hours, an optimized protocol for furniture and joinery products was developed. Surface quality observations, bulk density and weight change were used to initially screen the efficacy of the treatment. The influence of the different thermal regimes on the level of modification are discussed. The efficacy of the treatment on regions of juvenile wood versus mature wood was also considered, as the difference in physical properties between juvenile and mature wood in untreated timber is significant and contributes to machining and working variability. The stability and machinability of large planks from the scale up were evaluated. The mild thermal modification shows

potential for interior applications, and eradicates many issues commonly associated with fast grown larch such as resin pockets and springback of the latewood after machining.

Key words: *Larix decidua*, thermal modification, machining, adding value, growth rate

Introduction

Forest cover in the United Kingdom is dominated by commercial softwood species: Sitka spruce (*Picea sitchensis*, 50.84% of conifer area), Scots pine (*Pinus sylvestris*, 16.67%), Douglas fir (*Pseudotsuga menziesii*, 3.52%) and three larch species (*Larix* spp., 9.63%); while in hardwood forest 16.38% of the area is oak woodlands (*Quercus robur* and *Q. petrea*),which are the main commercial activity (Forestry Commission, 2014). The spruce, Douglas fir and larch, and other minor conifer species were introduced to the UK in the 19th century, and were widely planted by the Forestry Commission during the 20th Century to fulfil the need to rapidly establish a reserve of timber. Seed provenances with fast growth rates were frequently favoured, and the maritime climate of the UK further increased the growth rate, leading to low numbers of rings per inch and low density. While the timber industry within the UK is well adapted to using home grown spruce and pine, the growth rate and machining issues (Figure 1) mean that larch remains a less favoured timber, despite favourable mechanical properties. Larch for construction and joinery is frequently imported from Europe or Scandinavia, due to the slower growth rate in these regions and greater suitability for cladding.

Figure 1. a) Fast grown untreated larch can be prone to difficulties in planing, such as the broken grain shown in this window frame. b) Difference in strength of the low density earlywood and high density latewood of larch can result in delamination at the growth ring boundary in planing.

The western regions of the UK, including Wales, tend to have stands of Japanese larch (*Larix kaempferi*), while the drier Eastern regions were planted with European larch (*L. decidua*) and the hybrid larch (*L.* x. *eurolepis*) may also be planted for its greater vigour. Within the past ten years the Japanese larch stands of the Southwest of England, Wales and Scotland have come under attack by *Phytopthera ramoram*, a fungal pathogen to which this species of larch shows poor resistance. The availability of a large volume of larch timber on the market has coincided with the period of this project, and driven interest in adding value to this timber. Thermal modification was identified as a suitable technology for the Welsh timber industry, and trials by small companies had favoured a lower temperature high steam process, with great variability of the method between locations and operators. During the project many of the key players in this area worked together to conduct a series of experiments and trials which led to a clearer definition of the protocol, a more unified approach and greater replicability between batches. Additional joinery and wood using companies were engaged to evaluate the timber produced, and to work on demonstration projects.

Thermal modification is a well developed technology within Europe (Hill 2006, Ormondroyd *et al.* 2015), with an increasing market in exterior joinery such as cladding and decking products. The mild thermal treatment investigated within this project operates at a lower temperature than the current market leading technologies (Spear *et al.* 2014, 2015a). The mild thermal modifications were conducted in three stages: drying, treatment and reconditioning. Stages that were a single working day in duration were chosen to allow small businesses to operate kilns on a single shift working pattern, unlike the continuous treatment schedules and high treatment temperatures used in the Thermowood process and other treatments conforming to DD CEN/TS 15679, for which a larger workforce is required. Fuller details of the treatment, including the definition of treatment phase (set temperature of the kiln) and treatment zone (duration above a specified threshold temperature) have been reported in Spear *et al.* (2015a). The mild thermal treatment has also been demonstrated to have a beneficial effect in controlling problems relating to the exudation of oleoresin (Spear *et al.* 2015b), by a drying process.

Materials & Methods

Thermal modification

Planks of Japanese larch were sourced from three sawmills within Wales using Welsh grown timber. Plank cross sections were 110 x 30mm and 155 x 38mm for the small (pilot scale) kiln and 155 x 25mm for full scale production. Planks were supplied at lengths of 3m for the full scale kiln, and cross cut to lengths of 90cm for use in the pilot scale kiln. Within the full scale kiln the planks were stacked with stickers aligned with the four threaded bar supports of the trolley. Downward force was applied at these four locations, throughout the thermal treatment, using a broad crosspiece held by a nut and spring restraint, which was tightened to a pre-defined level for a set volume of timber.

Thermal modifications were conducted in three stages: a drying day (120°C), a treatment day and a conditioning day (80°C). The conditions for the drying day and the conditioning day were consistent throughout the study, and all steps were conducted under continuous supply of steam to maintain elevated humidity. During the kiln trials the maximum temperature and resulting treatment phase parameters were varied to achieve 1.5 to 5 hours within the treatment zone.

After treatment, planks from selected locations within the stack were cut to provide moisture content samples to evaluate uniformity through the pack. Timber taken from between the cuts made for moisture content samples was available for testing mechanical and physical properties. The remainder of the pack was used for workshop trials and demonstrator projects.

Properties evaluation

The moisture content samples were weighed and measured when cut; after drying in an oven at 105°C and allowing to cool in a desiccator above silica gel; and after conditioning for two weeks at 20°C and 65% relative humidity. The moisture content was determined using the difference between weight when cut and the oven dry weight, related to the oven dry weight.

The bulk density of the planks was calculated using the mass and dimensions of the moisture content samples, both in the oven dry state and in the conditioned state. Moisture content sample data (weight and volume in the oven dry state) was also used to estimate the dry weight of the planks prior to treatment, and after treatment. This estimation is necessary to estimate the weight change due to the mild thermal modification.

Company trials and demonstrators

During the project four small businesses who use wood, and one timber merchant, were engaged with the consortium to discuss and work with the timber during the development stages. Small parcels of timber from the pilot scale and the full scale kiln were provided for use in operations routinely undertaken by the companies, such as window frame manufacture, furniture manufacture, production of regularized or moulded timber and painting and staining. The objective was for these companies to observe the handling and quality of the product, and feedback any issues encountered. As the project progressed, several of these prototypes and furniture items were used in showcasing the treated timber to new contacts, for example at trade fairs (Timber Expo, The Royal Welsh Show).

Results and Discussion

Properties evaluation

Variability of moisture content within the stack was monitored, and used to guide adjustments to air flow within the kiln and kiln schedule adjustments. The moisture content of timber sampled prior to kilning (18% ±0.2%) was reduced by the kiln schedule (to 4.6% ±0.3% for this example). The moisture content of samples was re-evaluated after conditioning for 2 weeks at 20°C and 65% r.h., and the untreated samples had attained a moisture content of 9.6% ±0.1%, while the treated samples had a conditioned moisture content of 7.34% ±0.2%. This indicates that equilibrium moisture content is slightly reduced for the mild thermally treated timber.

The bulk density of treated and untreated samples conditioned at 20°C and 65% r.h. is shown in Figure 2. It is clear that there is very little difference in the bulk density after treatment, and although a small reduction was observed, this was not statistically significant. This small density change corresponded to a small change in the estimated dry weight of the plank. For example in Run regular 4 (on the pilot scale kiln) the estimated dry weight was calculated based on moisture content samples as average 1.49kg untreated and 1.42kg treated, correlating to a weight loss per plank ranging from -0.48% to 8.53%. Within the full scale kiln this sampling method was not appropriate due to timber dimensions, however the similarities in density difference reported indicate that a similar weight change due to thermal treatment can be expected.

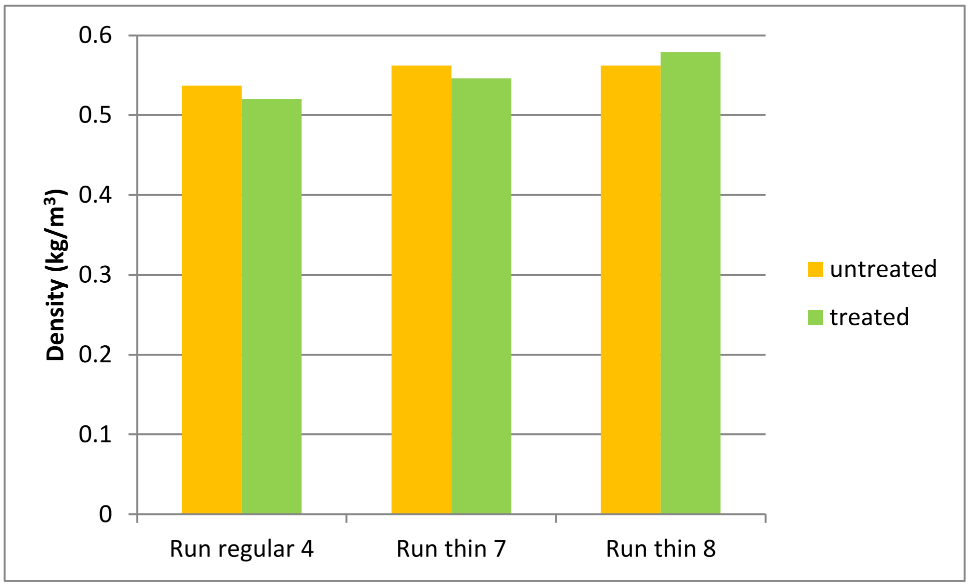

Figure 2. Bulk density of larch in the air dry state, untreated and after mild thermal modification treatment.

The density variation between planks was relatively large, and this related to the variation in levels of juvenile wood within the sampled planks. The timber had been sawn through and through, resulting in boards with either high mature wood or high juvenile wood content. The number of growth rings per inch (rpi) of the planks also showed wide variation. In the first study, values of 2.8 to 9.0 rpi were reported for timber from one supplier (Spear et al. 2015a). This data correlates to Run regular 4 in Figure 2. In later work with timber from a second sawmill, values ranged from 5.08 to 17.78 rpi, for timber which contained a greater proportion of mature wood, and had been sourced from a slower grown stand. In a third study on the timber used in the full scale production, which ws sourced from a different sawmill and another region of Wales, values between 5.08 and 26.67 rpi were observed (this correlates with Runs 7 and 8 in Figure 2). In producing batches of mild thermally treated timber for some applications, segregation of mature wood planks could be beneficial. However, the rpi values for the majority of the timbers sampled, even those containing mature wood, were lower than would typically be expected for Alpine grown European larch (*Larix decidua*) or Scandinavian grown Siberian larch (*Larix siberica*).

A large number of parameters were used in evaluating the timber quality from each treatment run, and observing variability within the stack of timber relating to hot and cold spots within the oven, especially during early runs on the pilot scale oven. For example distinct regions of high colour change and low moisture content were seen on the side from which the hot air was circulating. Thermocouple data for each plank confirmed that rate of temperature increase and duration in the treatment zone was higher for these timbers. Mechanical and physical properties were assessed on a plank by plank basis across the kiln an ideal 'mild' thermal treatment and 'moderate' thermal treatment were defined. Further adjustments to the kiln schedule and air flow allowed the mild thermal treatment to be achieved in a uniform manner across the whole stack of timber.

Company trials and demonstrators

After selection of the optimum treatment conditions, the parameters were transferred to the full scale kiln, and temperature within the stack and within the air was monitored to allow comparison with the pilot scale experimental work. The rate of heating and the air flow (controlling distribution of heat within the stack) were adjusted to suit the larger volumes of timber within the kiln. The product was a moderate not mild treatment, however this also remained below the treatment bracket of DD CEN/TS 15679.

Figure 3. a) Unloading mild thermally treated larch from the scale up treatment kiln. d) Planks were successfully laminated together and machined in a 4-head cutter. Photo credit Morwenna Spear.

A range of joinery and furniture items was made using both the mild and the moderate treated timbers, by companies within the project consortium. A laminated moulding for a window frame, using mild treated larch, is shown in Figure 3b. The ability to laminate thermally modified planks together to form a suitable cross section work piece for mouldings was seen as high priority by the project consortium, to allow the timber to be used in a wider range of products. Surface quality of the mouldings, and the routed profiles made by different companies, was good, with relatively little breaking of the grain.

A range of different products were manufactured (Figure 4), utilizing many different bonding and jointing techniques. Both PVA and isocyanate based glues worked well in the workshop. Occasional problems were reported for nailed or screwed joints if located close to the edge of the piece. This appeared to relate to weakness at the early-wood-latewood interface. The products took paints and varnishes well, and the relatively light colour of the treated product was seen as a benefit, and meant that varnishes and stains were often chosen to finish products.

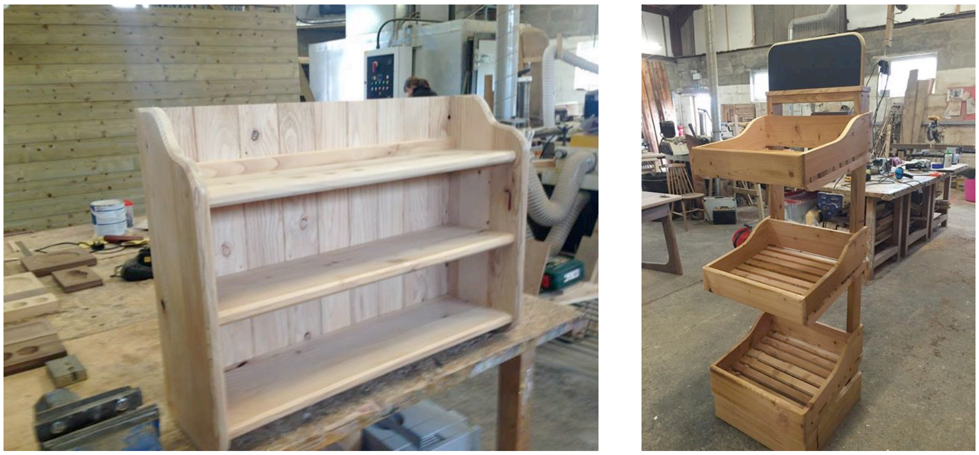

Figure 4. The thermally treated larch was used to make various interior joinery products, demonstrating the smooth machined surface and natural colour of the timber. Photo credits: Phil Jones.

Dissemination was an important aspect of the project, and the timber was shown at several events to gain comments from additional companies and the general public. Working with two of the project partners further demonstration activities were undertaken, with full scale production continuing to supply timber for a new build factoray and visitor centre at a local tourist attraction (Figure 5b).

Figure 5. a) Display stand in Coed Cymru's Ty Unnos Pavilion at the Royal Welsh Show, Builth Wells, Powys. b) Cladding installed at a visitor attraction on Anglesey as a demonstration project. Photo credits: Morwenna Spear.

Summary and Conclusions

The project worked with small businesses within Wales, to develop a protocol for mild thermal modification of larch timber. The timber retains a natural appearance, which was widely accepted in demonstrator events and discussion with the timber industry. The mild modification does not alter durability, but does significantly reduce machining defects relating to the wide growth rings and large difference in density between earlywood and latewood within each growth ring. The benefits are a smooth, easily worked timber suitable for interior joinery. The process was designed to best suit small enterprises, and to be suitable for enterprises with a very small work force. The next steps are to enagage with sufficient companies to increase product throughput and develop a market within the UK.

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